



THE NATIONAL NUMERACY NETWORK

Quantitative Reasoning (QR): A Program for Student Success

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Outline:

- QR Course
- QR Program
- QLR Assessment



THE NATIONAL NUMERACY NETWORK

“A well-established and highly studied construct, **numeracy** encompasses not just mathematical ability but also a disposition to engage quantitative information in a reflective and systematic way and use it to support valid inferences .”

-Dan Kahan et.al.

“Quantitatively literate citizens need to know more than formulas and equations. They need a predisposition to look at the world through mathematical eyes, to see the benefits (and risks) of thinking quantitatively about commonplace issues, and to approach complex problems with confidence in the value of careful reasoning. Quantitative literacy **empowers** people by giving them tools to think for themselves, to ask intelligent questions of experts, and to **confront authority confidently**. These are skills required to thrive in the modern world.”

-*Mathematics and Democracy* 2001

In short, how do we create a ~~mathematics~~ QR curriculum which teaches our students how to **THINK**?

Is Algebra Necessary?

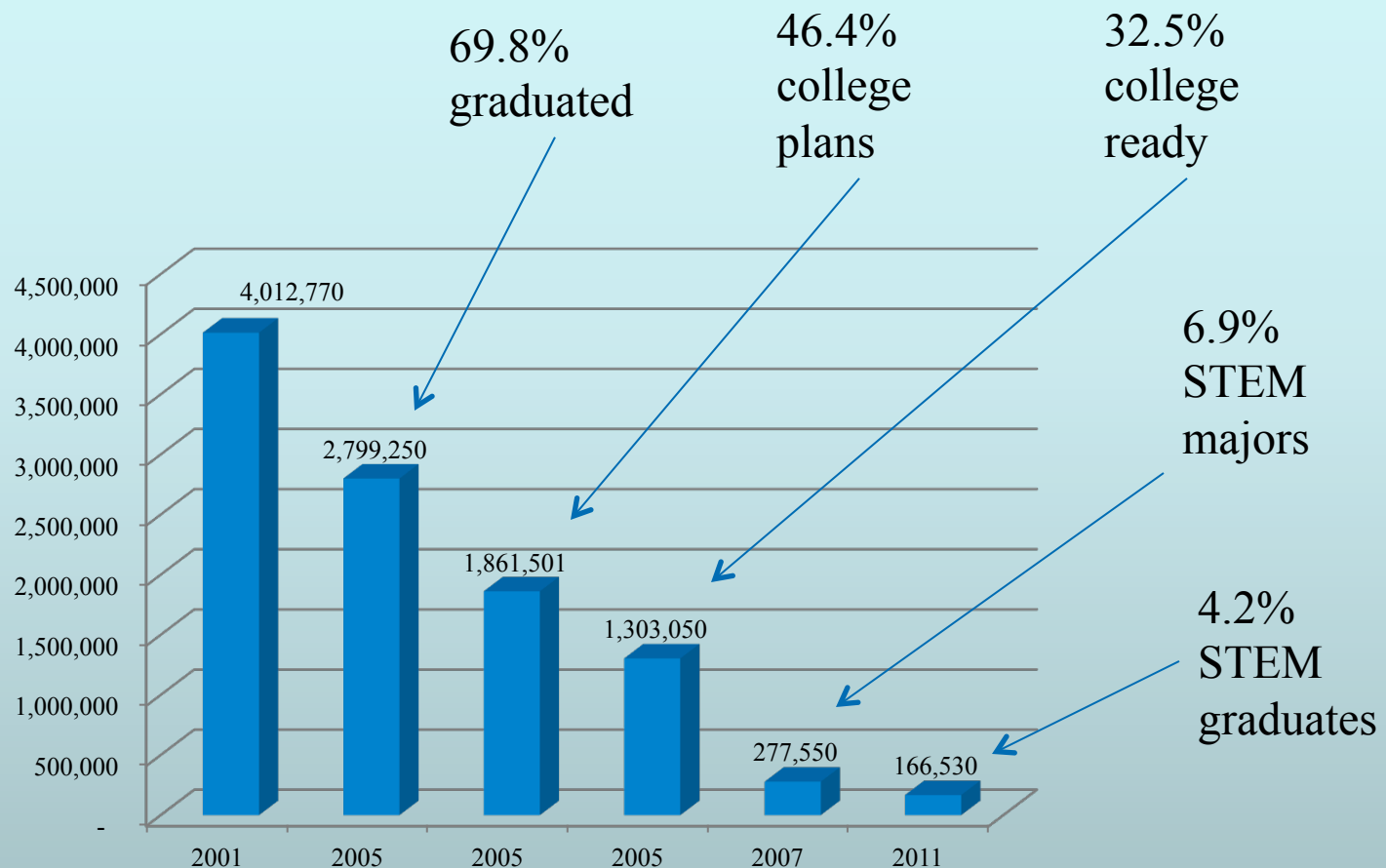
- Andrew Hacker Professor Emeritus CUNY
New York Times July 29, 2012

“A typical American school day finds some six million high school students and two million college freshman struggling with algebra.”

“I’m not talking about **quantitative skills**, critical for informed citizenship and personal finance, but a very different ballgame.”

“What is needed is **not textbook formulas** but greater understanding of where various numbers come from and what they actually convey.”

2001 Cohort 9th Graders



This is not a pipeline... it is a trickle. 60% of STEM workforce is 45 and older.

How Much Math Do We Really Need?

- Professor Emeritus U. Ill. Chicago
Washington Post 10/22/2010

“Unlike literature, history, politics and music, math has **little relevance** to everyday life.”

“All the math one needs in real life can be **learned in early years** without much fuss.”

“Most adults have no contact with math at work, nor do they curl up with an **algebra** book for relaxation.”



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Algebra as Business Math

“Few in business today make use of the mathematics they learned in school.

Spreadsheets have entirely different requirements.”

“Mathematical reasoning in workplaces **differs markedly** from the algorithms taught in school.”

“Make no mistake; the revolution in business math created by the spreadsheet is conceptual as well as physical. **It changes the way people in business think** about and approach problems as well as the way they work through results. It enables them to quantify **a whole new range of problems.**”

Impatience with Irresolution

Sitcom Culture: Problems should not take more than 30 minutes, be easy to understand, and have a happy ending.

Problem Solving vs. Modeling

-Modeling for Insight

Powell and Batt

• Well Structured Problems

- Objective Clear
- Assumptions Obvious
- Data available
- One right answer

• Examples:

- Solve $2x - 5/x = 12$ for x .
- Balance the books.
- Do your taxes.
 - Hopefully this is well structured!

• Ill Structured Problems

- Objectives, Assumptions, Data ambiguous

• Examples

- Should the Red Cross pay for blood donations?
- Should we tax soda?
- How much should an advertiser allocate to creative over delivery of ad?
- Should spreadsheets be taught K-12?

Tolerance for Ambiguity

Problem Solving vs. Modeling

-Modeling for Insight

Powell and Batt

- Ill Structured Problems are **Explored**
 - Make assumptions
 - Formulate Hypotheses
 - Generate Insights (don't "solve!")
- Modeling Process
 - Frame the Problem
 - Diagram the Problem
 - Influence Diagrams (relationships between variables)
 - Build a Model
 - **Spreadsheet Engineering**/ Parametrization
 - Sensitivity/ Strategy Analysis
 - Generate Insights
 - Iterate!

N Ways to Apply Algebra with the New York Times

-Patrick Honner

September 26, 2012

- Amortization
 - Buy versus lease
 - Make Assumptions (e.g., “solve!”)
- Evaluating College Rankings
 - “Use data to rank schools”
- Calculating School Quality
 - “Create score”
- Metro Card Math
 - Unlimited card or ride by ride?
- Olympic Algebra
 - “Compare and contrast average speeds of athletes over time, across events, and by gender.”
- Stock Portfolios
 - Compound interest formula, exponential growth, and compare different rates of return.

Modeling Process

Frame the Problem

Diagram the Problem

Influence Diagrams (relationships between variables)

Build a Model

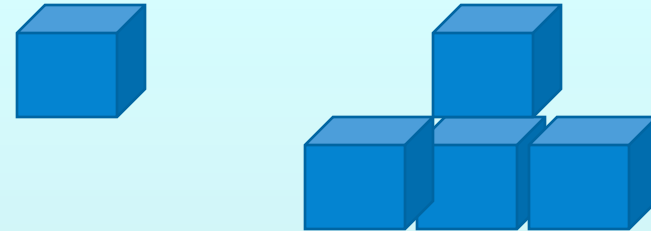
Spreadsheet Engineering/ Parametrization

Sensitivity/ Strategy Analysis

Generate Insights

Iterate!

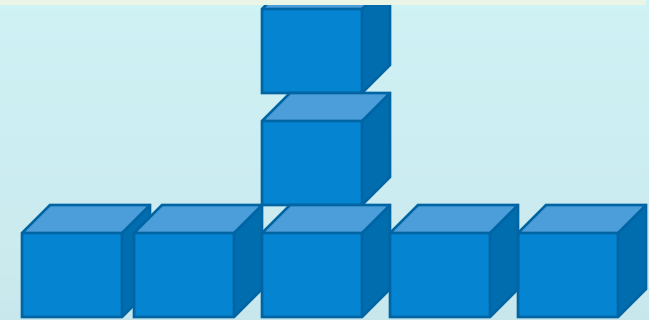
Building Blocks



How many blocks will there be in the n^{th} building?

Building N	Number of Blocks			
n	Recursion	$1 + 3(n-1)$	$3n - 2$	
1	1	1	1	1
2	4	4	4	4
3	7	7	7	7
4	10	10	10	10
5	13	13	13	13

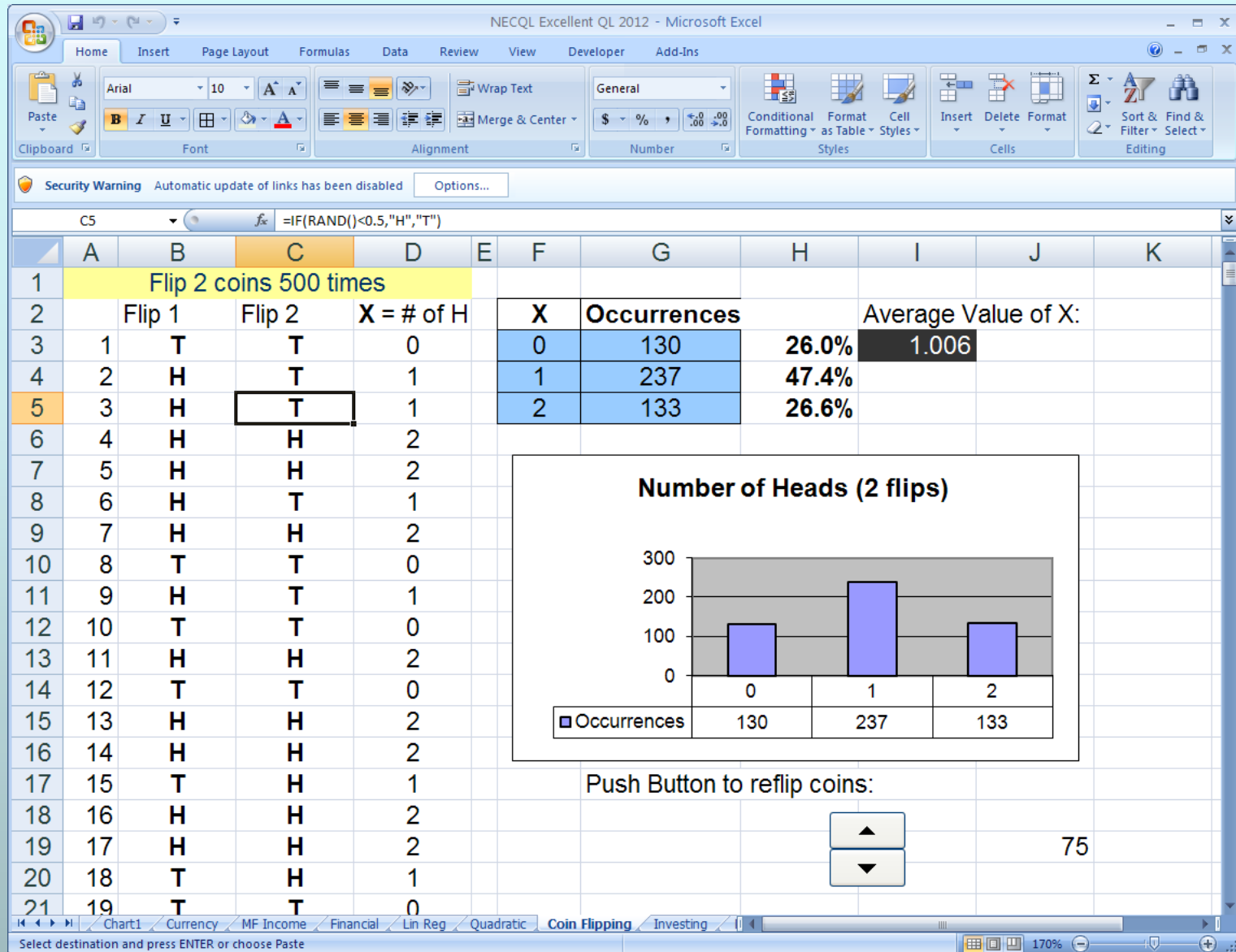
A **better** way to teach algebra, not get rid of algebra.



Building Number	Number of Blocks		
n	Recursion	$1 + 3(n-1)$	$3n - 2$
1	1	$=1+3*(A3-1)$	$=3*A3-2$
2	$=B3+3$	$=1+3*(A4-1)$	$=3*A4-2$
3	$=B4+3$	$=1+3*(A5-1)$	$=3*A5-2$
4	$=B5+3$	$=1+3*(A6-1)$	$=3*A6-2$
5	$=B6+3$	$=1+3*(A7-1)$	$=3*A7-2$

Probability and Coin Flips

Math as a LAB science.
Empirical Observations



Ratio and Proportion

$$E = 4/3 * D$$

Or is it
 $E = 3/4 * D$??

NECQL Excellent QL 2012 - Microsoft Excel

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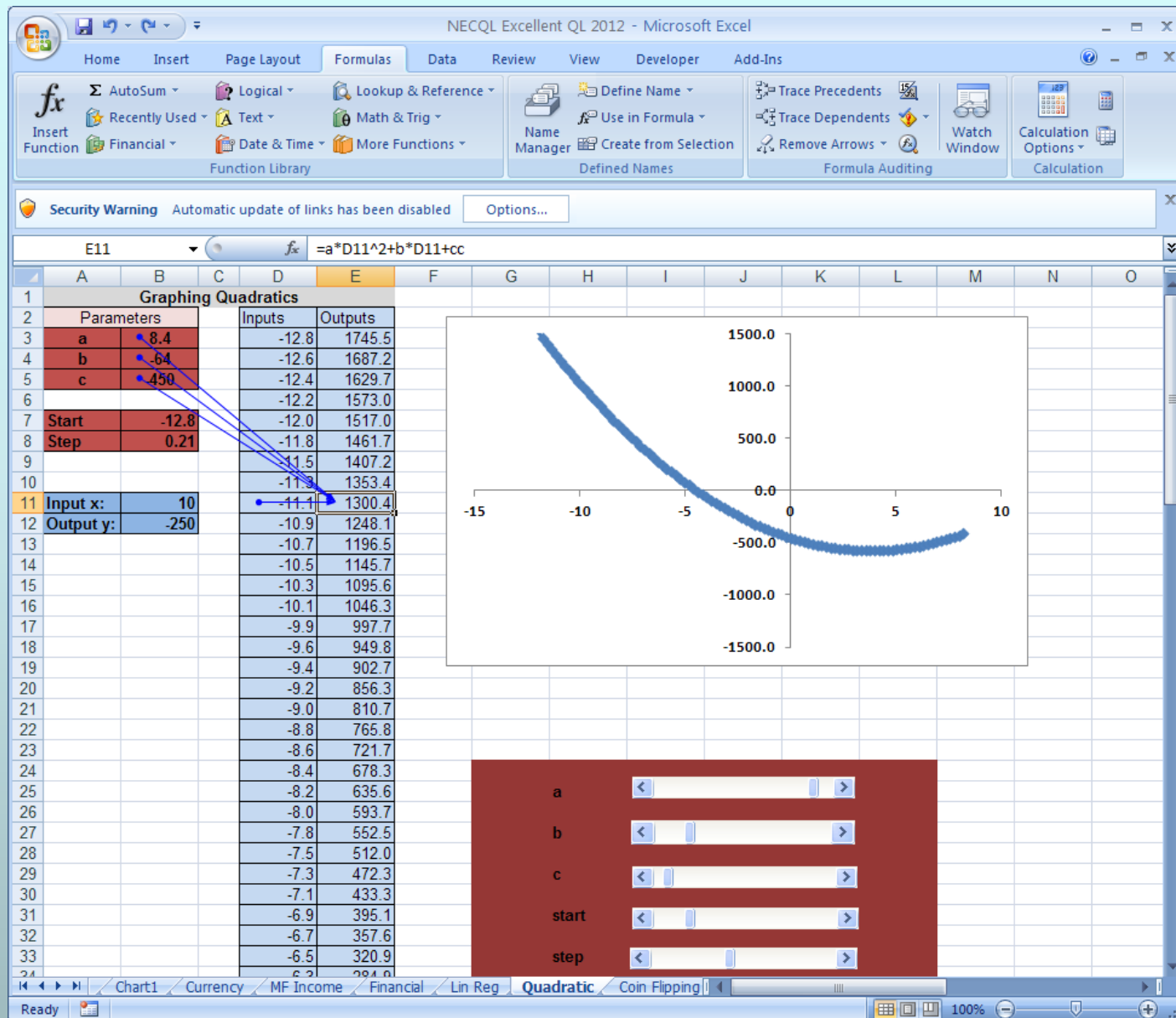
PERMUT X ✓ fx =Euros/Dollars*InputUSD

	A	B	C	D	E	F	G
1	Currency Converter						
2		Dollars	Euros	Yen			
3		\$ 4.00	€ 3.00	¥ 500.00			
4							
5		Input Dollars:	\$ 62.00				
6			Output Euros:	=Euros/Dollars*InputUSD			
7			Output Yen:	¥ 7,750.00			
8							
9		Input Euros:	€ 76.00				
10			Output Dollars:	\$ 101.33			
11			Output Yen:	¥ 12,666.67			
12							
13		Input Yen:	¥ 7,765.00				
14			Output Dollars:	\$ 62.12			
15			Output Euros:	€ 46.59			

Chart1 Currency MF Income Financial Lin Reg Quadratic Coin Flipping

Enter

Graphing in Real Time



Modeling Car Cost

	Focus	Prius			
Cost	\$ 20,000.00	\$ 33,000.00			
			Gallons per 100 miles		
MPG Hway	28	45	3.571	2.222	
MPG City	22	37	4.545	2.703	
			Gallons Used		
Miles Hway	8,000		285.71	177.78	
Miles City	12,000		545.45	324.32	
Price per Gallon	\$ 3.86	Total Gallons	831.17	502.10	
		Cost:	\$ 3,208.31	\$ 1,938.11	
	Gas Savings per year:		\$ 1,270.20		
		Extra Cost:	\$ 13,000.00		
	Years to recoup:		10.23	years	

Modeling Car Cost



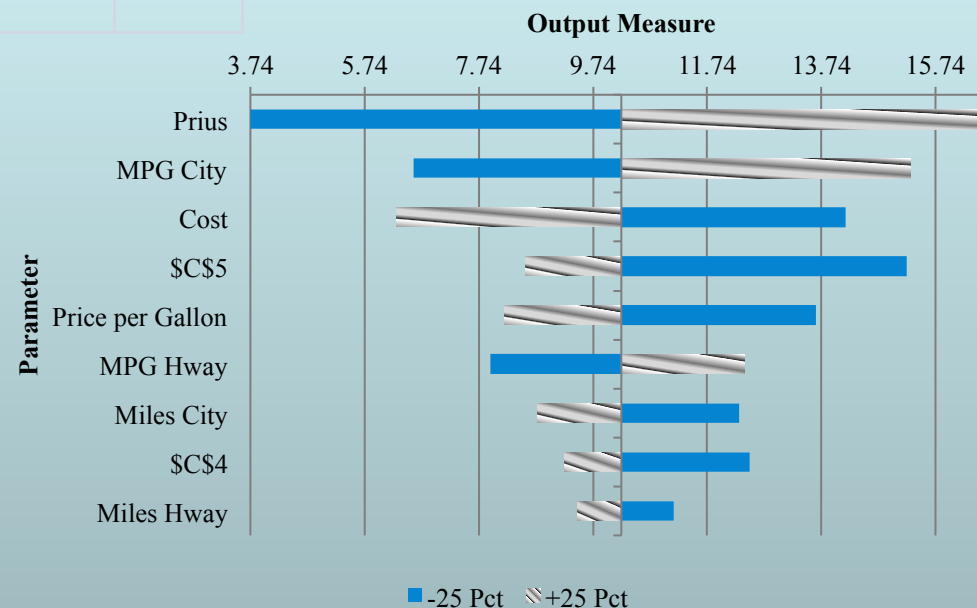
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		Years to recoup:	10.23	years

Which parameter has the greatest impact on the years to recoup extra cost of the Prius?

Is Algebra Necessary?
Yes! And we can use
spreadsheets and modeling to
help teach students why.

Tornado Sensitivity Chart



“41.1% of blacks were arrested in 1997, which means 7.4 out of every 1,000 people was a violent black criminal...”

Really? So 56.8% of whites were arrested for violent crimes as well?...

Black and White Victimization's and Arrests for Crimes of Violence 1997

	Number	Percent	Rate
Victimization			
White	7,068,590	82.1	37.1
Black	1,306,810	15.2	46.8
Arrests			
White	284,523	56.8	1.5
Black	205,823	41.1	7.4

Quantitative **Literacy**: Communicating (Reading and Writing) with Numbers NOT just Arithmetic

Counting 1, 2, 3,...

- They Counted With

- Centenarians?

- 1970: 106,441
 - 1980: 32,194
 - 2010: 53,364

- Homeless?

- 1980: 3,000,000
 - Who is “homeless”?

- Student Loan Default Rates Rise Sharply in Past Year

- 8.8% of all borrowers defaulted in the past year ending Sept. 30, up from 7%...

- What does “default” mean?
 - 2 year default rate

- Only 37% have paid back on time since 2005

Damned Lies and Statistics: The Social Construction of Statistics by Joel Best

1. Who created this statistic?
2. Why was this statistic created?
3. How was this statistic created?

Counting 1, 2, 3,...

- How big is that?
 - Keen sense of proportion... RATIOS!
 - Anorexia Deaths: 150,000 (1994)
 - Mutant Statistic: only 55,500 women 15-44 died that year!
- US Household Debt
 - Record \$13.8 trillion in 2011
- Is that a BIG number?
 - ~\$46,000 per person
 - \$884/week per person for 1 year (using \$15.6 billion as a yardstick)

Percentage of What?



- Drunk drivers account for 1/3 of all accidents...
 - So sober drivers are twice as dangerous?

Fraction of Accidents due to:	
Drunk Drivers	1/3
Sober Drivers	2/3

- 25-34 year olds get in 10 times as many accidents as 16 year olds...

	# accidents 2009:	# drivers:
16 year olds	229	1,000
25-34 year olds	89	1,000

- Men account for 55% of all accidents
 - But drive 63% of the miles

What's the Chance of That?

- One slice of bacon a day increases risk of colorectal cancer in men by 21%
 - For every \$1.00 increases to \$1.05 is clearly a 5% increase. Risk of breast cancer increases by 6%...
 - **Oops!** Risk of breast cancer increases by 6% for every extra alcohol 1% increases to 6% is clearly **NOT** 5% increase.
 - Where did we start?
- Start: 5 in 100 men get colorectal cancer in their lifetime.
 - Add bacon every day and about 6 out of 100 would.
- Start: 9 in 100 women will get breast cancer in their lifetime.
 - Add 2 drinks a day and about 10 in a 100 would.



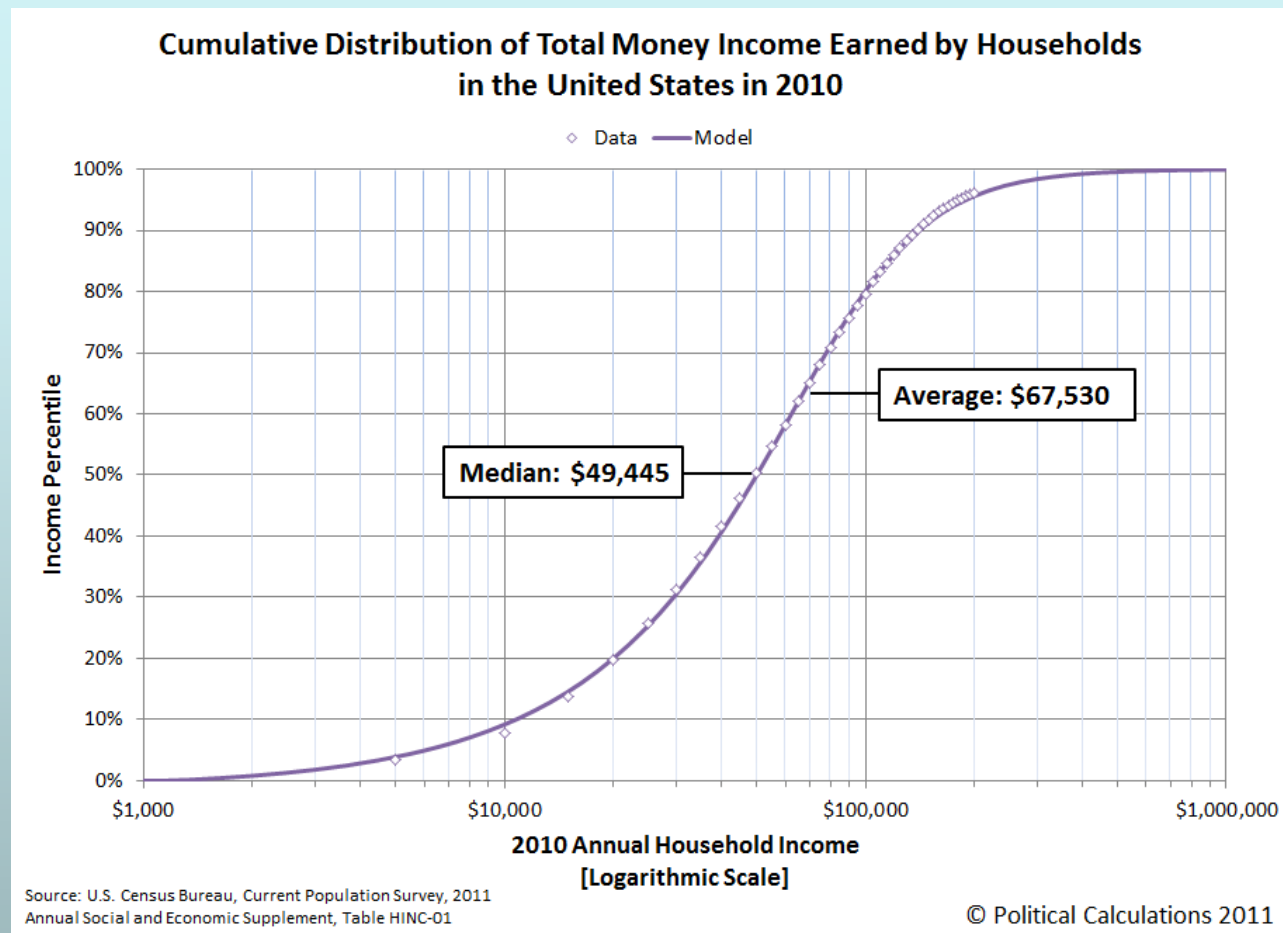
“In other words, translating a ratio to a percentage is not just a mathematical operation, but also a rhetorical practice in which artistic appeals are manipulated.” - Joanna Wolfe

- Women are 68% percent more likely than men to experience depression in their lifetimes.
- Over 75% of women never experience depression in their lifetime.
- 17.1 percent of individuals have experienced depression in their lifetime.
- Over 1 in 5 women and 1 in 8 men have experienced depression in their lifetimes.
- Approximately four of every ten depressed individuals is a man.

Statistics: 21.3% of women and 12.7% of men have experienced depression in their lifetime.

How Average...

- Statistical Literacy:



How Average...

- Speaking of Mean People:
- What household income do you need to make to be in the top 10%?
- What percentage of income tax do the top 1% pay?
- How many standard deviations from the mean is someone in the top 0.01% at \$35 million? ($N = 11,000$)
 - 92 standard deviations
 - A person who is 92 sd from mean in height would be 27 feet tall!

Math 050: Quantitative Reasoning

- Pre-Post Assessments

Math 50: QR Spring 2011			
	Pre-Qzscore	Post-Qzscore	Total Improvement
Mean	-1.219	-0.253	0.966
StDev	0.905	0.913	
Math 50: QR Fall 2011			
	Pre-Qzscore	Post-Qzscore	Total Improvement
Mean	-1.337	-0.210	1.127
StDev	0.670	0.913	
Math 50: QR Fall 2012			
	Pre-Qzscore	Post-Qzscore	Total Improvement
Mean	-1.45	-0.230	0.916
StDev	0.694	0.607	

The QLR Assessment Project



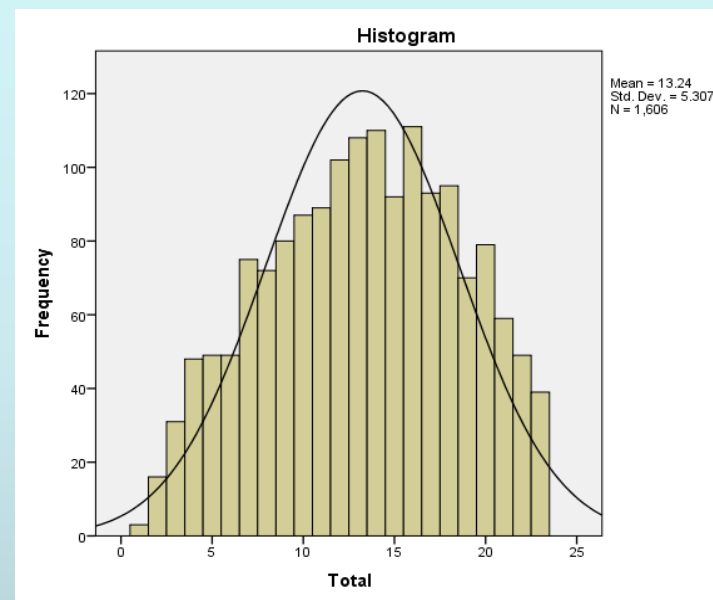
- NSF TUES: Transforming Undergraduate Education in STEM, DUE 1140562
- Type I, 2 year pilot project
 - Create QLRA instrument
 - Create Website for Administering Test
- Combined Bowdoin, Colby-Sawyer, and Wellesley exams
- 10 Institutions and 1,659 students
- Mean 13.44 questions correct out of 23 (58.4%; $sd = 5.35$)
- LAS Schools ($N = 1,011$) Mean 15.28 (66.4%; $sd = 4.60$)

Institution	Frequency	Percent
Bates	115	6.9
Bowdoin	100	6
Carleton	53	3.2
Colby-Sawyer	64	3.9
Central Washington	270	16.3
Edmonds CC	79	4.8
Holy Cross	652	39.3
Lansing CC	130	7.8
Southern Maine CC	105	6.3
Wellesley	91	5.5
Total	1659	100



The QLRA 13

- 13 questions identical to the Bowdoin Q-exam questions
 - #2, 7, 8, 9, 13, 15, 16, 17, 18, 19, 21, 22, 23
- Bowdoin 2012 Q-exam 30 questions (N = 497)



	Correl	Mean QLRA 13		STDEV QLRA 13	
Total QLRA	0.959	6.82	52.5%	3.315	25.5%
Bowdoin	0.913	9.02	69.4%	2.72	20.9%



The Bowdoin QR Exam

- 30 question entrance exam used for advising
 - Under 50% on Bowdoin Q-exam criteria for Math 050 ($N = 50$)
- Lessons Learned
 - Replace procedural, algorithmic questions with more involved reasoning, critical thinking questions.
 - Ask students to interpret tables and charts rather than doing it for them.
 - Focus on quantitative literacy, using numbers in meaningful sentences rather than just computation.
 - Ask students to postulate possible explanations for statistics rather than traditional logic games.



The Bowdoin QR Exam

- 30 question entrance exam used for advising
 - Under 50% on Bowdoin Q-exam criteria for Math 050 (N = 50)
- Significant predictor of GPA (N = 3,000)
 - Cumulative GPA $r = 0.39$
 - MCSR GPA $r = 0.48$
- Strongly correlated with 1st year Cum GPA $r = 0.48$
- Multivariate Regression Models ($R^2 = 0.30$ Cum GPA and $R^2 = 0.36$ MCSR GPA)



- M
- R
- T

Holding All Other Variables Constant		
	Q-score 30%	Q-score 80%
Cum GPA	3.2	3.5
MCSR GPA	2.7	3.5

Cum GPA and

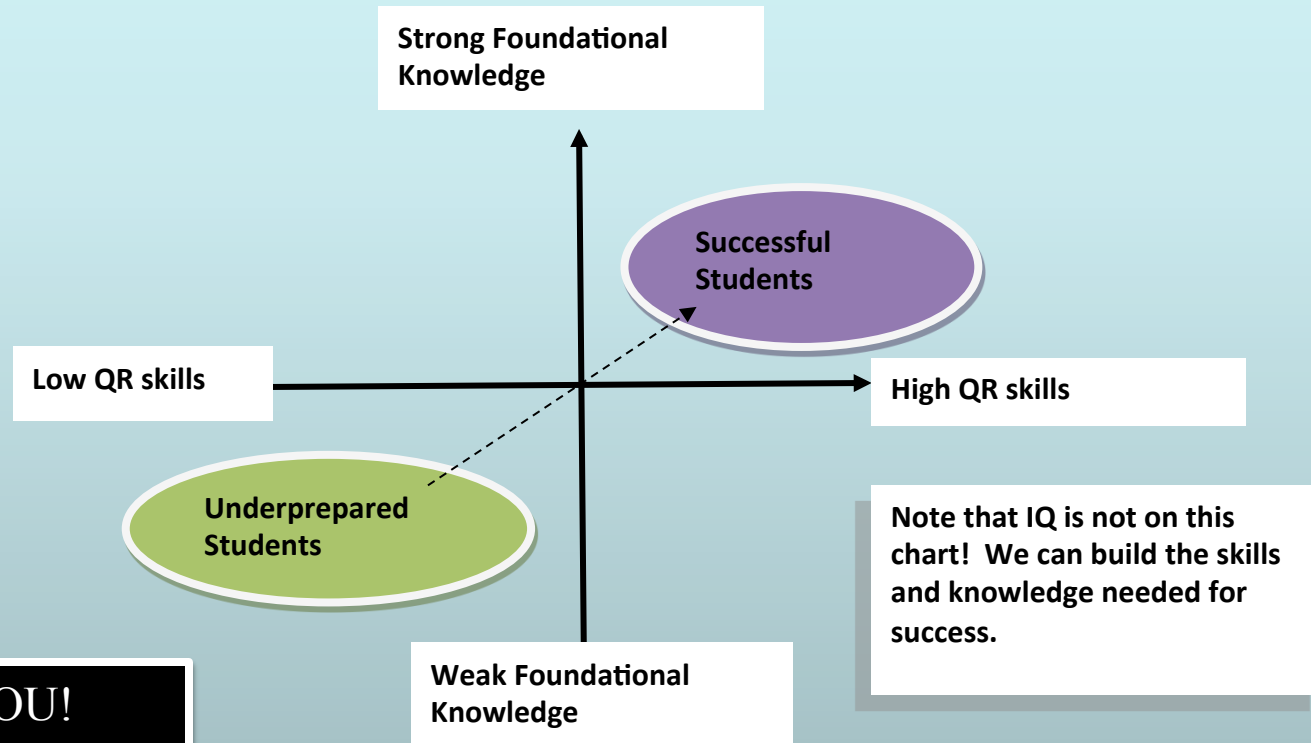
ference in GPA

associated with a 10 percentage point increase in respective aptitude test, with **all** other variables in model held constant.

Cumulative GPA Multivariate Regression Coefficients		
Math SAT	Q-score	Verbal SAT
0.0345	0.0603	0.0857
MCSR GPA Multivariate Regression Coefficients		
Math SAT	Q-score	Verbal SAT
0.1711	0.1599	0.0357

Scaffolding Student Success

- Math 1050: QR is an ENTRY point
- Math 1050: QR as a foundation for Calculus and Social Science
- Math 1050: QR is an EXIT point
- Future Work



THANK YOU!
Questions?